

SPECKLE INTERFEROMETRY AT THE U.S. NAVAL OBSERVATORY. XIX

BRIAN D. MASON, WILLIAM I. HARTKOPF, AND HALEY M. HUROWITZ¹
U.S. Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC 20392-5420, USA;
bdm@usno.navy.mil, wih@usno.navy.mil, hurowitz@mit.edu
Received 2013 June 4; accepted 2013 July 2; published 2013 August 2

ABSTRACT

The results of 2916 intensified CCD observations of double stars, made with the 26 inch refractor of the U.S. Naval Observatory, are presented. Each observation of a system represents a combination of over two thousand short-exposure images. These observations are averaged into 1584 mean relative positions and range in separation from 0''.54 to 98''.09, with a median separation of 11''.73. This is the 19th in this series of papers and covers the period 2012 January 5 through 2012 December 18. Also presented are 10 pairs that are reported for the first time, 17 pairs that appear to be lost, linear elements for 18 pairs, and orbital elements for 2 additional pairs.

Key words: binaries: general – binaries: visual

Online-only material: color figure, machine-readable and VO tables

1. INTRODUCTION

This is the 19th in a series of papers from the U.S. Naval Observatory's speckle interferometry program, presenting results of observations obtained at the USNO 26 inch telescope in Washington, DC (see, most recently, Mason et al. 2012). Over 27,000 mean positions have now resulted from this program since its inception by Charles Worley, Geoff Douglass, and colleagues in the early 1990s (see Douglass et al. 1997).

From 2012 January 5 through 2012 December 18, the 26 inch telescope was used on 63 of 246 (26%) scheduled nights. While most nights were lost due to weather conditions, time was also lost due to equipment upgrades, mechanical issues, and to a lack of observing personnel. With the primary camera off-site, all observations were obtained with the secondary camera, described in Mason et al. (2007).

Most of the systems observed with this camera have separations well beyond the regime in which there is any expectation of isoplanicity, so we classify the observing technique for all of these measures as just "CCD astrometry," rather than speckle interferometry. Despite this classification, there is an expectation that the resulting measurements have smaller errors than classical long focus CCD astrometry. Each measurement is the result of many hundreds of correlations per frame, and up to several thousand frames per observation. This ensemble of observations is processed and measured using the conventional directed vector autocorrelation techniques used by the CHARA and USNO speckle teams for over 20 years.

Individual nightly totals varied substantially, from 4 to 111 objects per night (mean 43.8). The results yielded 2758 observations and 2812 resolutions. Observations of multiple star systems in a single CCD field gives the somewhat non-intuitive result where the number of resolutions exceed the number of observations. After removing marginal observations, calibration data, tests, and "questionable measures" a total of 2553 measurements remained. These "questionable measures" are not of inferior quality but represent significant differences from the last measure, often many decades ago. Before these measures are published they will need to be confirmed in a new observing season to account for any other errors such as pointing or

other identification problems. The tabulated list of these is retained internally and forms a "high priority observing list" for subsequent observing seasons.

These 2553 measures were grouped into 1584 mean relative positions, including 11 confirmations of double stars with only one previous observation. If a pair is going through rapid motion during the calendar year we present, when possible, multiple means obtained when the pair is observable over the year.

Observing list construction and calibration procedures remain the same as those described for the "secondary" camera in Mason et al. (2007). This method also allowed us to use double stars to evaluate the observing system accuracy and precision by observation of pairs with well characterized orbital or linear solutions. Evaluation of the ensemble of tabulated $O - C$ values in Table 3 allows the error to be grossly characterized as $\pm 1^{\circ}0$ in position angle and $\pm 1\% \rho$ in separation.

2. RESULTS

2.1. New Pairs

Table 1 presents coordinates and magnitude information from CDS² for 10 pairs which are presented here for the first time. All were observed as closer components to known systems or pairs in the same field of view. Column 1 gives the coordinates of the primary of the pair. Column 2 is the discoverer designation (where WSI = Washington Stellar Interferometer) number. Columns 3 and 4 give the visual magnitudes of the primary and secondary, and Column 5 notes the circumstance of the discovery. The mean double star positions (T , θ , and ρ) of these systems are given in Table 2.

2.1.1. CHARA 263

One of the pairs in Table 1 does not carry the WSI designation, but instead is designated CHR 263 (CHR = Center for High Angular Resolution Astronomy). This anonymous binary was observed in 1982 with the Mayall reflector on Kitt Peak with the CHARA Speckle Camera (see McAlister et al. 1987) as part of an effort to observe minor planets (see Roberts et al. 1995). It was noted as being "2' south of minor planet Virginia"

¹ Summer intern.

² Magnitude information is from one of the catalogs queried in the Aladin sky atlas, operated at CDS, Strasbourg, France.

| Report Documentation Page | | | Form Approved OMB No. 0704-0188 | |
|---|----------------|---|--|---|
| <p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p> | | | | |
| 1. REPORT DATE 02 AUG 2013 | 2. REPORT TYPE | 3. DATES COVERED 00-00-2013 to 00-00-2013 | | |
| 4. TITLE AND SUBTITLE Speckle Interferometry At The U.S. Naval observatory, XIX | | | 5a. CONTRACT NUMBER | |
| | | | 5b. GRANT NUMBER | |
| | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | | 5d. PROJECT NUMBER | |
| | | | 5e. TASK NUMBER | |
| | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC, 20392 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | |
| 13. SUPPLEMENTARY NOTES The Astronomical Journal, 146:56 (9pp), 2013 September | | | | |
| 14. ABSTRACT | | | | |
| 15. SUBJECT TERMS | | | | |
| 16. SECURITY CLASSIFICATION OF: a. REPORT b. ABSTRACT c. THIS PAGE unclassified unclassified unclassified | | | 17. LIMITATION OF ABSTRACT Same as Report (SAR) | 18. NUMBER OF PAGES 10 |
| 19a. NAME OF RESPONSIBLE PERSON | | | | |

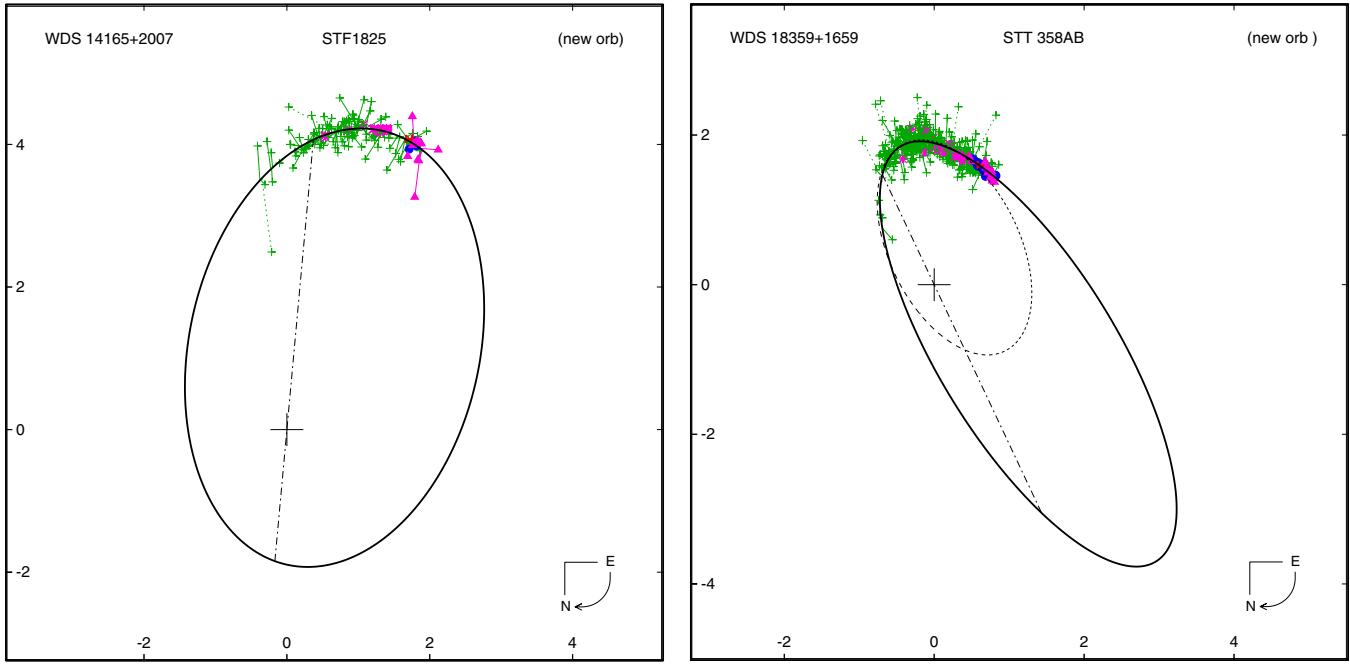


Figure 1. New orbital solutions, plotted together with all published data in the WDS database as well as the new data in Table 3. In each of these figures, micrometric observations are indicated by plus signs, interferometric measures by filled circles, *Hipparcos* measures are indicated by the letter “H.” “O – C” lines connect each measure to its predicted position along the new orbit (shown as a thick solid line). Dashed “O – C” lines indicate measures given zero weight in the final solution. A dot-dashed line indicates the line of nodes, and a curved arrow in the lower right corner of each figure indicates the direction of orbital motion. In the case of WDS18359+1659 the previous published orbit (Heintz 1995) is shown as a dashed ellipse.

(A color version of this figure is available in the online journal.)

Table 1
New Pairs

| Coordinates α, δ (2000) | Discoverer Designation | Mag _{primary} (V) | Mag _{secondary} (V) | Note |
|--|---------------------------|-------------------------------|---------------------------------|------|
| 07 31 48.21 –03 09 20.9 | WSI 31 AC | 11.00 | 11.23 | 1 |
| 07 32 17.53 –02 20 03.4 | WSI 141 AC | 11.36 | 13.3 | 1 |
| 01 05 44.56 +20 04 23.7 | WSI 144 AC | 10.31 | 13.5 | 1 |
| 04 07 08.49 +19 01 31.5 | WSI 145 Ba, Bb | 12.3 | 13.3 | 1 |
| 19 51 14.13 +38 00 41.1 | WSI 146 BC | 12.5 | 13.0 | 1 |
| 19 58 34.28 +34 24 36.1 | WSI 147 AC | 12.31 | 13.3 | 1 |
| 21 51 53.96 –05 08 55.4 | WSI 148 BC | 11.33 | 13.3 | 1 |
| 22 15 59.03 –02 54 07.9 | CHR 263 | 12.0 | 12.4 | 2 |
| 23 35 35.50 +43 44 44.6 | WSI 149 BC | 11.16 | 13.0 | 1 |
| 23 57 52.05 +56 42 25.6 | WSI 150 BC | 11.8 | 11.9 | 1 |

Notes.

1: Physicality status unknown, but closer than the known pair.

2: First measured by CHARA. See text.

and upon reduction this unpublished and unidentified pair was given the tongue-in-cheek moniker “Carolina” (i.e., south of Virginia). In 2011 the celestial location of Virginia at the time of the speckle observation was provided by James Hilton of the USNO Astronomical Applications Department and the pair was added to our observing list. This unknown pair is now confirmed 30 yr after the initial unpublished resolution. Coincidentally, MP (Minor Planet) 50 Virginia was discovered by James Ferguson at the Naval Observatory at its former location in Foggy Bottom on 1857 October 4.

2.2. Measures of Known Pairs

Table 2 presents the mean relative position of the members of 1359 systems having no published orbital or rectilinear elements. The first two columns identify the system by providing its

Table 2
ICCD Measurements of Double Stars

| WDS Design. α, δ (2000) | Discoverer Designation | Epoch 2000.+ | θ (°) | ρ (") | n | Note |
|--|---------------------------|-----------------|-----------------|---------------|---|------|
| 00004+7305 | HJ 3231 AB | 12.809 | 281.9 | 23.17 | 1 | |
| 00004+7305 | HJ 3231 AC | 12.809 | 296.3 | 44.72 | 1 | |
| 00012+1357 | WNO 12 | 12.014 | 204.0 | 11.61 | 2 | |
| 00019+6319 | BU 482 AB | 12.915 | 342.0 | 4.14 | 3 | |
| 00019+6319 | BU 482 AC | 12.915 | 124.6 | 10.36 | 2 | |
| 00026+6606 | STF 3053 | 12.907 | 70.6 | 15.14 | 2 | |
| 00036+4944 | FOX 53 | 12.858 | 192.0 | 3.79 | 2 | |
| 00051+6323 | HJ 1933 | 12.850 | 96.6 | 15.06 | 2 | |
| 00055+2736 | J 865 | 12.784 | 77.6 | 1.43 | 1 | |
| 00055+2736 | J 865 AC | 12.784 | 8.4 | 25.35 | 1 | |

Notes.

A: This is the vector addition of measures of other pairs.

B: Pair originally published as BVD 45 (Benavides et al. 2010), but with incorrect sign given to declination. Pair later “rediscovered” and published with correct declination; this latter discoverer designation has been maintained.

C: Confirming observation.

D: Motion non-linear, but insufficient for an orbital solution at this time.

E: The close pair, CHR 84Aa, Ab (unresolved here), recently had a combined solution orbit determined yielding masses of $M_a = 0.802 \pm 0.055 M_{\odot}$, $M_b = 0.622 \pm 0.053 M_{\odot}$ and an orbital parallax of 28.26 ± 1.70 milliarcseconds (mas). See C. D. Farrington et al. (2014, in preparation).

F: First measured by CHARA. See text.

N = 55–108: Number of years since last measure.

(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.)

epoch-2000 coordinates and discovery designation. Columns 3 through 5 give the epoch of observation (expressed as a fractional Besselian year), the position angle (in degrees), and the separation (in seconds of arc). Note that the position angle,

Table 3
Measurements of Systems with Orbits or Linear Solutions

| WDS Desig. α, δ (2000) | Discoverer Designation | Epoch 2000.+ | θ ($^{\circ}$) | ρ ($''$) | n | $O - C$ ($^{\circ}$) | $O - C$ ($''$) | Reference | Note |
|---------------------------------------|---------------------------|-----------------|----------------------------|--------------------|-----|---------------------------|---------------------|------------------------------|------|
| 00057+4549 | STT 547 | 12.858 | 186.9 | 6.02 | 3 | -0.8 | 0.09 | Popovic & Pavlovic (1996) | |
| | | | | | | -0.3 | -0.00 | Kiyaeva et al. (2001) | |
| 00057+4549 | STT 547 AE | 12.858 | 346.7 | 57.47 | 1 | 0.1 | 0.64 | Hartkopf & Mason (2011b) | |
| 00073+2058 | HDS 12 | 12.014 | 7.8 | 1.93 | 1 | -5.1 | 0.32 | Hartkopf & Mason (2011b) | |
| 00102+7507 | HJ 1938 | 12.809 | 349.7 | 23.03 | 2 | 0.3 | -0.08 | Hartkopf & Mason (2011b) | |
| 00175+0019 | STF 23 | 12.017 | 217.5 | 9.83 | 4 | -0.0 | 0.01 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 217.3 | 9.91 | 2 | -0.0 | -0.00 | Hartkopf & Mason (2011b) | |
| 00277-1625 | HJ 1968 | 12.029 | 234.0 | 35.64 | 3 | 0.2 | -0.07 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 234.1 | 35.92 | 1 | 0.3 | -0.05 | Hartkopf & Mason (2011b) | |
| 00360+2959 | STF 42 AB | 12.240 | 21.0 | 6.25 | 1 | 0.4 | -0.04 | Kiselev et al. (2009) | |
| | AC | 12.022 | 287.1 | 35.03 | 3 | 0.5 | -0.18 | Hartkopf & Mason (2011b) | |
| | AC | 12.832 | 287.1 | 35.49 | 2 | 0.1 | 0.04 | Hartkopf & Mason (2011b) | |
| | AC | 12.921 | 287.3 | 35.49 | 1 | 0.2 | 0.01 | Hartkopf & Mason (2011b) | |
| 00378+2443 | J 923 | 12.025 | 265.4 | 22.20 | 4 | 0.1 | 0.01 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 265.5 | 22.35 | 2 | 0.2 | 0.00 | Hartkopf & Mason (2011b) | |
| | | 12.921 | 265.5 | 22.34 | 1 | 0.2 | -0.03 | Hartkopf & Mason (2011b) | |
| 00396+8445 | HJ 1986 | 12.809 | 69.3 | 40.60 | 1 | 0.6 | 0.20 | Hartkopf & Mason (2011b) | |
| 00434-0054 | STF 53 | 12.025 | 3.3 | 51.00 | 2 | 0.0 | -0.05 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 3.4 | 51.00 | 1 | 0.0 | -0.25 | Hartkopf & Mason (2011b) | |
| 00502+1150 | STF 63 | 12.032 | 249.4 | 32.69 | 2 | 0.7 | -0.06 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 249.4 | 32.76 | 1 | 0.6 | -0.11 | Hartkopf & Mason (2011b) | |
| | | 12.932 | 249.4 | 32.84 | 1 | 0.6 | -0.04 | Hartkopf & Mason (2011b) | |
| 00521+1036 | STF 67 | 12.014 | 349.8 | 2.19 | 3 | -0.2 | -0.09 | Hartkopf & Mason (2011a) | |
| 01291+2143 | HO 9 | 12.019 | 42.7 | 52.47 | 2 | -0.0 | -0.13 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 42.3 | 52.32 | 1 | 0.1 | -0.12 | Hartkopf & Mason (2011b) | |
| 01399+1515 | STF 142 | 12.025 | 66.4 | 22.13 | 4 | 0.1 | -0.04 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 66.7 | 22.35 | 2 | 0.1 | 0.02 | Hartkopf & Mason (2011b) | |
| 01459+7142 | HJ 1089 | 12.809 | 89.2 | 26.34 | 2 | 0.3 | -0.24 | Mason et al. (2012) | |
| 01467+3310 | STF 158 | 12.858 | 270.1 | 2.08 | 3 | -2.3 | 0.03 | Hartkopf & Mason (2011a) | |
| 01510+2107 | STF 175 | 12.025 | 359.3 | 27.81 | 4 | 0.2 | -0.01 | Hartkopf & Mason (2011b) | |
| | | 12.862 | 359.4 | 27.91 | 4 | 0.2 | 0.00 | Hartkopf & Mason (2011b) | |
| | | 12.967 | 359.4 | 27.85 | 1 | 0.2 | -0.07 | Hartkopf & Mason (2011b) | |
| 01522+6627 | STF 167 | 12.915 | 313.9 | 31.42 | 1 | 0.5 | -0.18 | Hartkopf & Mason (2011b) | |
| 01543-1543 | GAL 314 | 12.019 | 1.0 | 35.82 | 2 | 0.2 | -0.04 | Hartkopf & Mason (2011b) | |
| | | 12.860 | 0.6 | 35.82 | 2 | 0.2 | -0.20 | Hartkopf & Mason (2011b) | |
| 01559+0151 | STF 186 | 12.014 | 248.4 | 0.72 | 1 | 0.3 | -0.09 | Brendley & Mason (2007) | |
| 02011+3518 | STF 197 | 12.858 | 232.5 | 37.35 | 2 | -0.1 | -0.74 | Hartkopf & Mason (2011b) | |
| 02020+0246 | STF 202 | 12.014 | 265.9 | 1.68 | 1 | 2.4 | -0.08 | Scardia (1983) | |
| 02157+6740 | ENG 10 | 12.850 | 327.0 | 24.79 | 2 | 0.6 | 0.01 | Hartkopf & Mason (2011b) | |
| 02213-1057 | HJ 3495 | 12.021 | 313.1 | 41.17 | 2 | 0.3 | 0.07 | Hartkopf & Mason (2011b) | |
| | | 12.866 | 313.0 | 41.19 | 1 | 0.2 | -0.00 | Hartkopf & Mason (2011b) | |
| 02556+2652 | STF 326 | 12.036 | 220.4 | 4.75 | 1 | -0.4 | -0.18 | Hartkopf & Mason (2011b) | |
| 02558+3429 | STF 325 | 12.036 | 147.6 | 22.47 | 2 | 0.6 | -0.01 | Hartkopf & Mason (2011b) | |
| | | 12.857 | 147.4 | 22.60 | 4 | 0.5 | 0.00 | Hartkopf & Mason (2011b) | |
| | | 12.915 | 147.5 | 22.62 | 2 | 0.6 | 0.02 | Hartkopf & Mason (2011b) | |
| 02563+7253 | STF 312 | 12.850 | 46.2 | 1.73 | 2 | 1.4 | -0.08 | Cvetkovic & Novakovic (2006) | |
| 02592+2120 | STF 333 | 12.066 | 209.1 | 1.35 | 1 | -0.4 | -0.01 | Rica (2012) | |
| 03344+2428 | STF 412 | 12.913 | 353.0 | 0.72 | 1 | 0.7 | -0.03 | Scardia et al. (2002) | |
| 03463+2411 | S 437 AB, C | 12.967 | 308.8 | 39.39 | 1 | 0.2 | -0.37 | Hartkopf & Mason (2011b) | |
| 04100+8042 | STF 460 | 12.102 | 143.6 | 0.68 | 1 | -4.0 | -0.01 | Scardia (2003) | |
| 04367+1930 | STF 567 | 12.091 | 343.7 | 1.89 | 1 | 1.5 | -0.14 | Seymour et al. (2002) | |
| 04382+7128 | HJ 1146 | 12.102 | 37.9 | 26.97 | 1 | 0.0 | -0.19 | Hartkopf & Mason (2011b) | |
| 04385+2656 | STF 572 | 12.091 | 189.2 | 4.24 | 4 | -0.1 | -0.08 | Hartkopf & Mason (2011b) | |
| 04550+3411 | HJ 351 | 12.132 | 77.6 | 18.72 | 1 | 0.5 | 0.34 | Friedman et al. (2011) | |
| 05079+0830 | STT 98 | 12.132 | 296.1 | 0.74 | 1 | 0.4 | -0.16 | Scardia et al. (2008) | |
| 05154+3241 | STF 653 | 12.028 | 10.4 | 10.08 | 1 | -0.5 | 0.03 | Table 5 | A |
| 05245-0224 | DA 5 | 12.094 | 77.6 | 1.65 | 1 | 0.2 | -0.14 | Hartkopf et al. (2012) | |
| 05308+0557 | STF 728 | 12.094 | 44.5 | 1.15 | 1 | 0.9 | -0.14 | Seymour & Hartkopf (1999) | |
| 05329-0631 | STF 735 | 12.094 | 350.2 | 57.56 | 1 | 0.2 | -0.15 | Hartkopf & Mason (2011b) | |
| 05418+1933 | STF 771 | 12.067 | 55.0 | 21.64 | 2 | 0.3 | 0.06 | Hartkopf & Mason (2011b) | |
| 05511+6545 | STF 780 AC | 12.102 | 148.0 | 12.20 | 2 | 1.0 | -0.66 | Hartkopf & Mason (2011b) | |
| 05524+3618 | AG 101 | 12.028 | 353.4 | 23.72 | 1 | 0.6 | 0.07 | Hartkopf & Mason (2011b) | |
| 06195+1220 | STF 892 | 12.105 | 40.6 | 39.45 | 1 | 0.1 | -0.02 | Friedman et al. (2011) | |
| 06278+2047 | SHJ 70 | 12.127 | 202.3 | 24.93 | 1 | -0.2 | -0.07 | Hartkopf & Mason (2011b) | |
| 06323+5225 | WOR 6 | 12.181 | 159.8 | 0.71 | 1 | 3.0 | -0.05 | Hartkopf & Mason (2009) | |

Table 3
(Continued)

| WDS Desig. α, δ (2000) | Discoverer Designation | Epoch 2000.+ | θ ($^{\circ}$) | ρ ($''$) | n | $O - C$ ($^{\circ}$) | $O - C$ ($''$) | Reference | Note |
|---------------------------------------|---------------------------|-----------------|----------------------------|--------------------|-------|---------------------------|---------------------|---------------------------|------|
| 06376+1211 | S 529 | 12.132 | 131.6 | 53.38 | 2 | 0.2 | -0.14 | Hartkopf & Mason (2011b) | |
| 06462+5927 | STF 948 | 12.175 | 69.2 | 1.77 | 6 | 1.4 | -0.11 | Mason et al. (2006) | |
| 06467+4335 | SHJ 75 | 12.155 | 41.1 | 29.26 | 3 | -0.1 | -0.12 | Hartkopf & Mason (2011b) | |
| 06482+5542 | STF 958 | 12.102 | 256.8 | 4.49 | 2 | -0.2 | -0.06 | Kiselev et al. (2009) | |
| | | | | | | 0.3 | 0.01 | Kiselev et al. (2009) | |
| 07057+5245 | STF 1009 | 12.182 | 148.0 | 4.24 | 3 | 0.1 | -0.09 | Hartkopf & Mason (2011b) | |
| 07346+3153 | STF 1110 | 12.105 | 56.2 | 4.58 | 1 | 0.9 | -0.23 | DeRosa et al. (2012) | |
| 08122+1739 | STF 1196 | 12.105 | 31.3 | 1.04 | 1 | 1.2 | -0.04 | Mason et al. (2006) | |
| 08243+4457 | STF 1217 | 12.255 | 242.2 | 29.04 | 2 | 0.1 | 0.39 | Kiselev et al. (2009) | |
| | | | | | | -0.4 | 0.19 | Kiselev et al. (2009) | |
| 08476+0001 | STF 1281 | 12.236 | 310.5 | 52.33 | 1 | 0.0 | 0.03 | Hartkopf & Mason (2011b) | |
| 08554+7048 | STF 1280 | 12.182 | 353.3 | 2.59 | 2 | -0.6 | -0.07 | Heintz (1997) | |
| | | 12.255 | 353.1 | 2.61 | 2 | -0.8 | -0.07 | Heintz (1997) | |
| 09079-0708 | STF 1316 AC | 12.237 | 277.8 | 7.61 | 3 | -0.1 | 0.04 | Hartkopf & Mason (2011b) | |
| | BC | 12.237 | 296.5 | 13.98 | 2 | 2.0 | 0.27 | Friedman et al. (2012) | |
| 10160+7928 | STF 1409 | 12.256 | 194.5 | 19.01 | 2 | 0.6 | -0.01 | Hartkopf & Mason (2011b) | |
| 10390+7839 | FOX 167 | 12.256 | 51.2 | 15.25 | 2 | 0.3 | 0.03 | Hartkopf & Mason (2011b) | |
| 10517-0340 | HDS 1551 | 12.302 | 322.5 | 2.69 | 2 | -2.3 | 0.25 | Table 5 | |
| 11131+4011 | HJ 494 | 12.259 | 140.3 | 31.18 | 1 | 0.2 | 0.04 | Table 5 | |
| 11170-0708 | BU 600 AC | 12.417 | 98.9 | 53.17 | 1 | 0.3 | -0.18 | Hartkopf & Mason (2011b) | |
| 11182+3132 | STF 1523 | 12.302 | 194.0 | 1.54 | 3 | -0.6 | -0.10 | Mason et al. (1995) | |
| | | 12.417 | 192.1 | 1.56 | 2 | -1.6 | -0.09 | Mason et al. (1995) | |
| 11245+2037 | STF 1537 | 12.286 | 357.8 | 2.19 | 1 | 0.0 | -0.02 | Table 5 | |
| 11268+0301 | STF 1540 | 12.417 | 149.6 | 28.18 | 2 | 2.7 | -0.46 | Hopmann (1960) | |
| 11296+1138 | HJ 2572 | 12.286 | 171.7 | 38.94 | 1 | 0.2 | -0.01 | Table 5 | |
| 11456+0354 | HJ 1196 | 12.302 | 204.1 | 45.78 | 1 | -0.1 | -0.02 | Hartkopf & Mason (2011b) | |
| | | 12.417 | 204.2 | 45.72 | 1 | -0.0 | -0.10 | Hartkopf & Mason (2011b) | |
| 12095-1151 | STF 1604 AB | 12.417 | 89.1 | 8.88 | 1 | 0.7 | -0.33 | Hartkopf & Mason (2011b) | |
| 12095-1151 | STF 1604 AC | 12.417 | 11.7 | 10.14 | 1 | -0.2 | -0.06 | Hartkopf & Mason (2011b) | |
| 12095-1151 | STF 1604 BC | 12.417 | 324.8 | 11.97 | 4 | 0.4 | 0.00 | Friedman et al. (2012) | |
| 12272+2701 | STF 1643 | 12.417 | 4.6 | 2.61 | 2 | 0.2 | -0.10 | Olevic & Cvetkovic (2003) | |
| | | | | | | -0.6 | -0.16 | Hartkopf & Mason (2011b) | |
| | | | | | | 0.2 | -0.12 | Mason et al. (2004a) | |
| 12417-0127 | STF 1670 | 12.302 | 13.5 | 1.72 | 2 | 0.0 | -0.11 | Scardia et al. (2007) | |
| | | 12.417 | 12.9 | 1.73 | 1 | -0.2 | -0.13 | Scardia et al. (2007) | |
| 13005-0604 | HJ 1224 | 12.302 | 283.4 | 16.50 | 2 | -0.3 | -0.12 | Hartkopf & Mason (2011b) | |
| 13084+1529 | STF 1722 | 12.415 | 336.8 | 2.54 | 1 | 0.7 | -0.12 | Table 5 | |
| 13092+0848 | A 1786 | 12.414 | 96.0 | 13.84 | 1 | 0.2 | -0.10 | Table 5 | |
| 13169+1701 | BU 800 | 12.415 | 104.6 | 7.23 | 1 | -0.2 | -0.47 | Hale (1994) | |
| 13550-0804 | STF 1788 | 12.141 | 99.9 | 3.55 | 2 | 0.3 | -0.02 | Hopmann (1970) | |
| 14165+2007 | STF 1825 | 12.439 | 153.9 | 4.20 | 1 | -0.4 | -0.16 | Table 4 | |
| 14287-1012 | STF 1847 | 12.124 | 270.3 | 36.74 | 2 | 0.1 | -0.17 | Hartkopf & Mason (2011b) | |
| | | 12.451 | 270.3 | 36.80 | 2 | 0.1 | -0.15 | Hartkopf & Mason (2011b) | |
| | | | | | | 0.2 | -0.12 | Mason et al. (2004a) | |
| 14307+8308 | LDS 1800 | 12.486 | 240.1 | 1.79 | 2 | 17.2 | 0.21 | Scardia et al. (2007) | |
| 14407+1625 | STF 1864 | 12.453 | 111.4 | 5.25 | 1 | 0.4 | -0.26 | Scardia et al. (2007) | |
| 14463+0939 | STF 1879 | 12.453 | 83.5 | 1.61 | 1 | -0.1 | -0.11 | Table 5 | |
| 14514+1906 | STF 1888 | 12.453 | 306.2 | 5.66 | 2 | 0.3 | -0.18 | Mason et al. (1999) | |
| 14516+1519 | HU 1153 | 12.453 | 295.7 | 2.97 | 1 | -0.0 | -0.24 | Söderhjelm (1999) | |
| 14595+5510 | STI 2317 | 12.486 | 123.3 | 34.04 | 1 | -0.1 | -0.01 | Hartkopf & Mason (2011b) | |
| 15006+1606 | KU 107 | 12.469 | 358.5 | 57.69 | 1 | -0.1 | 0.08 | Hartkopf & Mason (2011b) | |
| 15038+4739 | STF 1909 | 12.486 | 62.7 | 1.24 | 2 | -0.3 | -0.09 | Table 5 | |
| 15049+1014 | WFC 161 | 12.469 | 84.3 | 36.88 | 1 | -0.2 | -0.32 | Zirm (2011) | |
| 15111+4424 | SKF 10 | 12.486 | 281.2 | 13.26 | 2 | 0.1 | 0.22 | Table 5 | |
| 15230+1122 | AG 347 | 12.486 | 11.8 | 24.63 | 2 | -0.4 | 0.05 | Friedman et al. (2011) | |
| 15232+3017 | STF 1937 | 12.120 | 184.4 | 0.59 | 1 | -0.0 | -0.06 | Table 5 | |
| 15249+1359 | HJ 252 AC | 12.486 | 72.4 | 51.01 | 1 | 0.0 | -0.32 | Muterspaugh et al. (2010) | |
| 15280+1442 | STF 1945 | 12.120 | 312.6 | 40.89 | 1 | -0.1 | -0.72 | Hartkopf & Mason (2011b) | |
| | | 12.464 | 312.6 | 41.13 | 4 | -0.2 | -0.51 | Hartkopf & Mason (2011b) | |
| | | AC | 12.351 | 306.9 | 49.03 | -0.1 | -0.04 | Hartkopf & Mason (2011b) | |
| 15348+1032 | STF 1954 | 12.486 | 172.5 | 3.94 | 2 | 0.1 | -0.04 | Mason et al. (2004a) | |
| 15382+3615 | HU 1167 AB | 12.486 | 79.3 | 1.22 | 1 | -1.8 | -0.03 | Drummond et al. (1995) | |
| 15382+3615 | STF 1964 CD | 12.486 | 20.7 | 1.47 | 2 | 1.3 | -0.04 | Drummond et al. (1995) | |
| 15598+1723 | STF 1993 | 12.491 | 42.4 | 20.38 | 1 | -0.3 | -0.08 | Hartkopf & Mason (2011b) | |
| 16044-1122 | STF 1998 | 12.568 | 359.7 | 0.93 | 4 | -0.2 | -0.08 | Docobo & Ling (2009) | |
| | AC | 12.568 | 47.3 | 6.91 | 1 | 3.1 | -0.63 | Zirm (2008) | |

Table 3
(Continued)

| WDS Desig. α, δ (2000) | Discoverer Designation | Epoch 2000.+ | θ ($^{\circ}$) | ρ ($''$) | n | $O - C$ ($^{\circ}$) | $O - C$ ($''$) | Reference | Note |
|---------------------------------------|---------------------------|-----------------|----------------------------|--------------------|-----|---------------------------|---------------------|------------------------------|------|
| 16060+1319 | STF 2007 | 12.491 | 321.9 | 38.25 | 1 | -0.1 | 0.01 | Hartkopf & Mason (2011b) | |
| 16081+1703 | STF 2010 | 12.491 | 13.1 | 27.04 | 1 | -0.3 | -0.09 | Hartkopf & Mason (2011b) | |
| 16263+0211 | BAL 1915 AC | 12.568 | 8.0 | 50.17 | 1 | -0.2 | 0.00 | Hartkopf & Mason (2011b) | |
| 17146+1423 | STF 2140 | 12.469 | 103.7 | 4.60 | 2 | 0.5 | -0.05 | Baize (1978) | |
| 17174+2501 | SLE 24 | 12.469 | 15.8 | 39.88 | 1 | -0.7 | -0.11 | Hartkopf & Mason (2011b) | |
| 17275+1627 | A 2184 | 12.579 | 30.4 | 1.91 | 1 | -0.4 | -0.02 | Table 5 | |
| 17394-1546 | HU 181 | 12.543 | 37.8 | 0.90 | 1 | -5.4 | -0.11 | Hartkopf & Mason (2001) | |
| 17462+1019 | AG 356 | 12.543 | 215.8 | 14.38 | 2 | 0.1 | -0.16 | Friedman et al. (2012) | |
| 18031-0811 | STF 2262 | 12.696 | 286.9 | 1.46 | 2 | 1.0 | -0.13 | Söderhjelm (1999) | |
| 18359+1659 | STT 358 | 12.661 | 149.5 | 1.59 | 1 | 1.7 | 0.07 | Heintz (1995) | |
| | | | | | | 0.0 | -0.06 | Table 4 | |
| 18393+0700 | J 101 | 12.606 | 243.6 | 5.32 | 1 | 0.3 | -0.12 | Table 5 | |
| 18443+3940 | STF 2382 AB | 12.628 | 346.8 | 2.19 | 2 | 0.2 | -0.17 | Mason et al. (2004b) | |
| | | | | | | 0.4 | -0.11 | Novakovic & Todorovic (2006) | |
| 18443+3940 | STF 2383 CD | 12.628 | 77.6 | 2.26 | 2 | 0.6 | -0.12 | Docobo & Costa (1984) | |
| 18489+1615 | STF 2400 A, BC | 12.606 | 161.1 | 10.82 | 1 | 0.3 | 0.09 | Table 5 | |
| 18575+5814 | STF 2438 | 12.666 | 357.0 | 0.81 | 1 | -0.6 | -0.02 | Hartkopf & Mason (2001) | |
| 19059+3502 | HZG 13 | 12.434 | 136.3 | 27.07 | 1 | -0.3 | 0.04 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 136.4 | 27.07 | 2 | -0.4 | -0.03 | Hartkopf & Mason (2011b) | |
| 19121+4951 | STF 2486 | 12.734 | 204.4 | 7.22 | 2 | -0.2 | -0.06 | Hale (1994) | |
| 19168+6742 | STF 2514 | 12.434 | 350.7 | 23.04 | 2 | -0.4 | 0.13 | Hartkopf & Mason (2011b) | |
| | | 12.734 | 350.7 | 23.05 | 1 | -0.4 | 0.10 | Hartkopf & Mason (2011b) | |
| 19179+2522 | BUP 187 | 12.434 | 39.7 | 53.95 | 1 | -0.0 | -0.03 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 39.7 | 53.92 | 1 | -0.0 | 0.08 | Hartkopf & Mason (2011b) | |
| 19249+2126 | WSI 22 | 12.434 | 271.8 | 14.97 | 2 | 0.5 | 0.15 | Hartkopf & Mason (2011b) | |
| 19260+3555 | BU 1286 AB | 12.434 | 45.2 | 22.38 | 3 | 0.2 | 0.14 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 45.1 | 22.45 | 2 | 0.2 | 0.12 | Hartkopf & Mason (2011b) | |
| | BC | 12.680 | 210.1 | 20.20 | 8 | -0.1 | 0.14 | Hartkopf & Mason (2011b) | |
| 19418+5032 | STFA 46 | 12.628 | 133.1 | 39.66 | 1 | -0.3 | -0.05 | Hauser & Marcy (1999) | |
| 20020+2456 | STT 395 | 12.702 | 126.1 | 0.73 | 1 | 0.1 | -0.12 | Zirm (2013) | |
| 20111+1611 | HZG 15 AD | 12.434 | 256.8 | 35.99 | 1 | -0.5 | -0.40 | Friedman et al. (2011) | |
| 20182+2319 | POU 4348 | 12.732 | 163.5 | 28.32 | 1 | 0.1 | 0.15 | Friedman et al. (2011) | |
| 20333+3323 | HJ 1535 AC | 12.434 | 193.1 | 31.48 | 1 | -0.4 | 0.02 | Table 5 | |
| | AD | 12.434 | 229.6 | 58.46 | 1 | 0.2 | 0.06 | Hartkopf & Mason (2011b) | |
| | AD | 12.858 | 229.7 | 58.46 | 1 | 0.3 | -0.02 | Hartkopf & Mason (2011b) | |
| | AD | 12.926 | 229.7 | 58.49 | 1 | 0.3 | -0.01 | Hartkopf & Mason (2011b) | |
| 20387+3838 | STF 2708 | 12.434 | 322.9 | 56.19 | 1 | 0.1 | 0.01 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 323.1 | 56.24 | 1 | 0.2 | -0.05 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 323.0 | 56.26 | 1 | 0.1 | -0.05 | Hartkopf & Mason (2011b) | |
| 20396+4035 | STT 410 | 12.666 | 4.6 | 0.83 | 1 | 0.6 | -0.04 | Hartkopf & Mason (2011a) | |
| 20423+4549 | STT 411 | 12.434 | 348.6 | 31.42 | 1 | -0.2 | 0.07 | Hartkopf & Mason (2011b) | |
| | | 12.666 | 348.7 | 31.47 | 1 | -0.1 | 0.09 | Hartkopf & Mason (2011b) | |
| 20425+4916 | ARG 39 | 12.434 | 181.8 | 14.70 | 2 | -0.1 | 0.02 | Hartkopf & Mason (2011b) | |
| | | 12.595 | 181.8 | 14.70 | 2 | -0.1 | 0.00 | Hartkopf & Mason (2011b) | |
| | | 12.666 | 181.9 | 14.74 | 1 | 0.0 | 0.03 | Hartkopf & Mason (2011b) | |
| 20450+1244 | BU 64 | 12.781 | 352.4 | 0.62 | 2 | -2.3 | -0.03 | Brendley & Hartkopf (2007) | |
| 20467+1607 | STF 2727 | 12.705 | 265.7 | 8.99 | 2 | 0.5 | -0.03 | Hale (1994) | |
| 21008-0821 | BU 678 | 12.781 | 258.1 | 2.72 | 1 | -4.9 | -0.14 | Seymour et al. (2002) | |
| 21069+3845 | STF 2758 | 12.858 | 152.1 | 31.39 | 2 | 0.6 | -0.04 | Gorshanov et al. (2006) | |
| 21124-1500 | H 1 47 | 12.492 | 309.3 | 4.18 | 2 | 20.0 | 0.95 | Hopmann (1974) | |
| | | | | | | 0.6 | 0.02 | Hartkopf & Mason (2011b) | |
| 21186+1134 | BU 163 | 12.697 | 258.1 | 0.79 | 1 | -0.3 | -0.05 | Fekel et al. (1997) | |
| 21200+5259 | STF 2789 | 12.595 | 113.9 | 6.85 | 2 | -0.1 | -0.03 | Kiselev et al. (2009) | |
| | | | | | | -0.5 | 0.12 | Kiselev et al. (2009) | |
| 21208+3227 | STT 437 | 12.651 | 19.4 | 2.31 | 4 | 0.3 | -0.10 | Hartkopf & Mason (2011a) | |
| 21238-0635 | S 788 | 12.492 | 92.8 | 56.89 | 1 | -0.1 | -0.50 | Hartkopf & Mason (2011b) | |
| | | 12.697 | 92.8 | 56.95 | 1 | -0.1 | -0.47 | Hartkopf & Mason (2011b) | |
| | | 12.703 | 92.8 | 56.94 | 2 | -0.1 | -0.48 | Hartkopf & Mason (2011b) | |
| | | 12.781 | 92.8 | 56.92 | 1 | -0.0 | -0.50 | Hartkopf & Mason (2011b) | |
| | | 12.859 | 92.8 | 56.94 | 2 | -0.1 | -0.50 | Hartkopf & Mason (2011b) | |
| | | 12.934 | 92.8 | 56.94 | 1 | -0.1 | -0.50 | Hartkopf & Mason (2011b) | |
| 21289+1105 | STF 2799 | 12.492 | 260.8 | 1.67 | 2 | 1.4 | -0.19 | Hartkopf & Mason (2011a) | |
| 21296+3625 | ES 258 | 12.705 | 35.0 | 10.15 | 2 | -0.1 | 0.00 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 35.0 | 10.11 | 2 | -0.1 | -0.02 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 35.0 | 10.08 | 2 | -0.2 | -0.04 | Hartkopf & Mason (2011b) | |

Table 3
(Continued)

| WDS Design. α, δ (2000) | Discoverer Designation | Epoch 2000.+ | θ ($^{\circ}$) | ρ ($''$) | n | $O - C$ ($^{\circ}$) | $O - C$ ($''$) | Reference | Note |
|--|---------------------------|-----------------|----------------------------|--------------------|-----|---------------------------|---------------------|----------------------------|------|
| 21337+3728 | SEI 1526 | 12.705 | 159.8 | 25.43 | 2 | 1.2 | 0.11 | Hartkopf & Mason (2011b) | |
| | | 12.858 | 159.9 | 25.11 | 2 | 1.4 | -0.23 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 160.0 | 25.14 | 2 | 1.4 | -0.21 | Hartkopf & Mason (2011b) | |
| 21434-0605 | SCA 90 | 12.702 | 261.5 | 41.19 | 1 | 0.4 | -0.89 | Hartkopf & Mason (2011b) | |
| 21436-1108 | LV 10 | 12.702 | 352.0 | 0.96 | 1 | -2.3 | 0.12 | Seymour et al. (2002) | |
| 21441+2845 | STF 2822 | 12.667 | 316.4 | 1.60 | 1 | -2.4 | -0.00 | Heintz (1995) | |
| 21520+5548 | STF 2840 | 12.595 | 196.0 | 17.67 | 2 | 0.2 | -0.08 | Hartkopf & Mason (2011b) | |
| 21582+8252 | STF 2873 | 12.735 | 66.6 | 13.76 | 2 | 0.4 | 0.02 | Grosheva (2006) | |
| | | | | | | 0.5 | 0.03 | Grosheva (2006) | |
| 22038+6438 | STF 2863 | 12.849 | 275.0 | 8.00 | 2 | 1.1 | -0.38 | Zeller (1965) | B |
| 22086+5917 | STF 2872 BC | 12.849 | 297.3 | 0.75 | 1 | -0.3 | -0.06 | Seymour et al. (2002) | |
| 22143+1711 | STF 2877 | 12.667 | 23.4 | 23.47 | 1 | 0.1 | 0.34 | Hartkopf & Mason (2011b) | |
| | | 12.866 | 23.6 | 23.30 | 1 | 0.3 | 0.15 | Hartkopf & Mason (2011b) | |
| 22159+5440 | BU 377 | 12.907 | 57.7 | 32.43 | 1 | -1.9 | -3.67 | Hartkopf & Mason (2011b) | |
| | AC | 12.907 | 46.1 | 30.33 | 1 | -4.9 | -3.69 | Friedman et al. (2011) | |
| 22288-0001 | STF 2909 | 12.492 | 167.0 | 2.03 | 2 | -1.0 | -0.16 | Scardia et al. (2010) | |
| 22378+3641 | ES 216 | 12.874 | 37.1 | 52.47 | 1 | -0.0 | -0.17 | Hartkopf & Mason (2011b) | |
| 22400+0113 | A 2099 | 12.866 | 165.0 | 0.70 | 1 | 0.9 | -0.09 | Hartkopf & Mason (2010) | |
| 22435+4602 | STT 477 | 12.858 | 261.1 | 21.65 | 1 | 0.1 | -0.02 | Hartkopf & Mason (2011b) | |
| 22478-0414 | STF 2944 AB | 12.781 | 302.0 | 1.80 | 1 | -0.1 | -0.07 | Zirm (2007) | |
| | AC | 12.781 | 86.5 | 59.99 | 1 | 0.1 | -0.33 | Hartkopf & Mason (2011b) | |
| | AC | 12.866 | 86.7 | 60.34 | 1 | 0.3 | 0.00 | Hartkopf & Mason (2011b) | |
| | AC | 12.926 | 86.4 | 59.97 | 1 | 0.1 | -0.38 | Hartkopf & Mason (2011b) | |
| | BC | 12.781 | 85.6 | 61.57 | 1 | -1.7 | -0.65 | Hartkopf & Mason (2011b) | A |
| 22490+6834 | STF 2947 | 12.735 | 55.8 | 4.65 | 2 | 0.4 | -0.01 | Hartkopf & Mason (2011b) | |
| 22557+1547 | HU 987 | 12.858 | 77.6 | 1.08 | 1 | -0.4 | -0.04 | Brendley & Hartkopf (2007) | |
| 23045+3123 | ES 396 | 12.868 | 303.5 | 34.34 | 4 | -0.0 | 0.22 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 303.5 | 34.35 | 2 | 0.0 | 0.21 | Hartkopf & Mason (2011b) | |
| 23097+1512 | STF 2983 | 12.862 | 269.6 | 39.02 | 2 | 0.1 | -0.58 | Hartkopf & Mason (2011b) | |
| | | 12.926 | 269.7 | 38.94 | 1 | 0.2 | -0.66 | Hartkopf & Mason (2011b) | |
| 23186+6807 | STF 3001 | 12.811 | 222.2 | 3.24 | 2 | -0.1 | -0.11 | Docobo et al. (2003) | |
| 23192+6131 | ES 1863 AC | 12.856 | 150.2 | 9.86 | 6 | -0.2 | 0.32 | Hartkopf & Mason (2011b) | |
| 23208+0227 | STF 3002 | 12.866 | 197.0 | 3.82 | 1 | 0.1 | 0.19 | Hartkopf & Mason (2011b) | |
| 23397-0440 | HJ 990 | 12.866 | 278.0 | 46.12 | 1 | 0.2 | -0.14 | Hartkopf & Mason (2011b) | |
| 23398-0420 | HWE 99 | 12.866 | 66.6 | 46.71 | 1 | -0.3 | 0.18 | Hartkopf & Mason (2011b) | |
| 23401+1258 | HU 1325 | 12.953 | 30.4 | 0.80 | 1 | -5.8 | 0.18 | Olevic & Jovanovic (2001) | |
| | | | | | | 1.0 | -0.05 | Scardia (2003) | |
| 23460-1841 | H 2 24 | 12.913 | 135.5 | 6.62 | 2 | 0.2 | -0.30 | Table 5 | |
| 23536+5131 | STTA 251 | 12.932 | 207.9 | 47.67 | 2 | 0.3 | -0.10 | Hartkopf & Mason (2011b) | |
| 23595+3343 | STF 3050 | 12.795 | 338.2 | 2.23 | 1 | -0.0 | -0.09 | Hartkopf & Mason (2011a) | |
| 23596-0748 | BU 731 | 12.913 | 296.6 | 1.62 | 1 | -0.6 | -0.05 | Table 5 | |

Notes.

A: This is the vector addition of measures of other pairs.

B: The close pair, MCA 69Aa, Ab (unresolved here), recently had a combined solution orbit determined yielding masses of $M_a = 1.045 \pm 0.031 M_{\odot}$, $M_b = 0.408 \pm 0.066 M_{\odot}$ and an orbital parallax of 38.10 ± 2.81 milliarcseconds (mas). See C. D. Farrington et al. (2014, in preparation).

Table 4
New Orbital Elements

| Element | Unit | HR 5346 | HR 6981 |
|-----------------------------------|-------------------------|------------|------------|
| WDS | α, δ (2000) | 14165+2007 | 18359+1659 |
| Discoverer designation | | STF1825 | STT 358 AB |
| Period (P) | years | 755.6 | 1109.8 |
| Semimajor axis (a'') | arcsec | 3.205 | 3.923 |
| Inclination (i) | ($^{\circ}$) | 133.7 | 109.6 |
| Longitude node (Ω) | ($^{\circ}$) | 174.8 | 205.2 |
| Epoch periastron (T_0) | years | 1661.6 | 1836.4 |
| Eccentricity (e) | | 0.453 | 0.664 |
| Longitude periastron (ω) | ($^{\circ}$) | 213.9 | 301.8 |
| Orbit grade | | 5 | 4 |

measured from north through east, has not been corrected for precession, and is thus based on the equinox for the epoch of observation. Objects whose measures are of lower quality are indicated by colons following the position angle and separation. These lower-quality observations may be due to one or more of the following factors: close separation, large magnitude difference, one or both components being very faint, a large zenith distance, and poor seeing or transparency. They are included primarily due to either the confirming nature of the observation or the number of years since the last measured position. The sixth column indicates the number of independent measurements (i.e., observations obtained on different nights) contained in the mean, and the seventh column flags any notes. The 1359 measurements in Table 2 have a mean separation of $16.^{\circ}92$, and a median separation of $11.^{\circ}14$.

Table 5
New Linear Elements

| WDS α, δ (2000) | Discoverer Designation | x_0 ($''$) | a_x ($'' \text{ yr}^{-1}$) | y_0 ($''$) | a_y ($'' \text{ yr}^{-1}$) | T_0 (yr) | ρ_0 ($''$) | θ_0 (deg) |
|--------------------------------|---------------------------|-------------------|-----------------------------------|-------------------|-----------------------------------|---------------|----------------------|---------------------|
| 05154+3241 | STF 653 AB | 3.736 | 0.02998 | -9.115 | 0.0123 | 2074.672 | 9.851 | 22.29 |
| 10517-0340 | HDS 1551 | 0.515 | 0.15591 | -0.916 | 0.0876 | 2026.167 | 1.051 | 29.32 |
| 11131+4011 | HJ 494 | 7.630 | 0.05247 | 27.330 | -0.0146 | 1778.458 | 28.375 | 164.40 |
| 11245+2037 | STF 1537 | 0.764 | 0.00084 | -0.348 | 0.0018 | 3028.755 | 0.840 | 65.50 |
| 11296+1138 | HJ 2572 | -8.912 | 0.05745 | 34.751 | 0.0147 | 1758.260 | 35.875 | 194.38 |
| 13084+1529 | STF 1722 | -0.539 | 0.00104 | 0.114 | 0.0049 | 2531.563 | 0.551 | 258.04 |
| 13092+0848 | A 1786 | 0.020 | 0.09071 | -0.176 | 0.0104 | 1861.110 | 0.177 | 6.56 |
| 14407+1625 | STF 1864 AB | 3.937 | -0.00500 | 3.378 | 0.0058 | 2254.407 | 5.188 | 130.63 |
| 15006+1606 | KU 107 | 13.445 | -0.06413 | -53.878 | -0.0160 | 1781.644 | 55.530 | 14.01 |
| 15049+1014 | WFC 161 | 0.020 | 0.48115 | -3.750 | 0.0025 | 1936.876 | 3.750 | 0.30 |
| 15230+1122 | AG 347 | 0.429 | 0.07230 | -24.108 | 0.0013 | 1947.878 | 24.112 | 1.02 |
| 15249+1359 | HJ 252 AC | 36.274 | 0.04028 | 15.026 | -0.0972 | 1699.689 | 39.263 | 112.50 |
| 17275+1627 | A 2184 AB | -0.449 | 0.00983 | -0.619 | -0.0071 | 1867.765 | 0.765 | 324.07 |
| 18393+0700 | J 101 | 0.291 | -0.02309 | 1.212 | 0.0056 | 1790.391 | 1.246 | 166.48 |
| 18489+1615 | STF 2400 A, BC | -1.340 | 0.03279 | 0.690 | 0.0637 | 1865.609 | 1.507 | 242.77 |
| 20333+3323 | HJ 1535 AC | 11.905 | -0.14829 | 13.155 | 0.1342 | 1883.907 | 17.742 | 137.85 |
| 23460-1841 | H 2 24 | -0.984 | 0.00714 | 1.911 | 0.0037 | 1194.851 | 2.150 | 207.25 |
| 23596-0748 | BU 731 | -1.553 | 0.00088 | -0.176 | -0.0078 | 1937.605 | 1.563 | 276.45 |

Table 6
Orbit and Linear Ephemerides

| WDS α, δ (2000) | Discoverer Designation | 2012.0 | | 2014.0 | | 2016.0 | | 2018.0 | | 2020.0 | |
|--------------------------------|---------------------------|--------------------------|--------------------|--------------------------|--------------------|--------------------------|--------------------|--------------------------|--------------------|--------------------------|--------------------|
| | | θ ($^\circ$) | ρ ($''$) |
| 05154+3241 | STF 653 AB | 10.6 | 10.059 | 11.0 | 10.046 | 11.4 | 10.033 | 11.7 | 10.021 | 12.1 | 10.009 |
| 10517-0340 | HDS 1551 | 321.8 | 2.743 | 325.1 | 2.416 | 329.3 | 2.100 | 335.1 | 1.799 | 342.9 | 1.523 |
| 11131+4011 | HJ 494 | 140.3 | 31.097 | 140.1 | 31.141 | 139.9 | 31.186 | 139.7 | 31.232 | 139.5 | 31.277 |
| 11245+2037 | STF 1537 | 357.7 | 2.220 | 357.8 | 2.216 | 357.8 | 2.212 | 357.8 | 2.209 | 357.9 | 2.205 |
| 11296+1138 | HJ 2572 | 171.6 | 38.904 | 171.5 | 38.950 | 171.3 | 38.996 | 171.1 | 39.043 | 171.0 | 39.089 |
| 13084+1529 | STF 1722 | 336.1 | 2.669 | 336.1 | 2.659 | 336.0 | 2.649 | 336.0 | 2.639 | 335.9 | 2.630 |
| 13092+0848 | A 1786 | 95.8 | 13.779 | 95.8 | 13.961 | 95.8 | 14.144 | 95.9 | 14.327 | 95.9 | 14.509 |
| 14165+2007 | STF 1825 | 154.3 | 4.357 | 154.0 | 4.352 | 153.7 | 4.346 | 153.3 | 4.340 | 153.0 | 4.334 |
| 14407+1625 | STF 1864 AB | 110.9 | 5.512 | 111.0 | 5.506 | 111.2 | 5.501 | 111.3 | 5.496 | 111.5 | 5.491 |
| 15006+1606 | KU 107 | 358.7 | 57.580 | 358.6 | 57.615 | 358.4 | 57.650 | 358.3 | 57.686 | 358.2 | 57.722 |
| 15049+1014 | WFC 161 | 84.4 | 36.341 | 84.5 | 37.298 | 84.7 | 38.256 | 84.8 | 39.214 | 84.9 | 40.172 |
| 15230+1122 | AG 347 | 11.9 | 24.554 | 12.2 | 24.581 | 12.6 | 24.610 | 12.9 | 24.639 | 13.2 | 24.669 |
| 15249+1359 | HJ 252 AC | 72.6 | 51.204 | 72.4 | 51.340 | 72.2 | 51.476 | 72.0 | 51.612 | 71.9 | 51.749 |
| 17275+1627 | A 2184 AB | 30.5 | 1.910 | 30.8 | 1.932 | 31.0 | 1.954 | 31.3 | 1.977 | 31.6 | 1.999 |
| 18359+1659 | STT 358 AB | 149.8 | 1.645 | 148.9 | 1.641 | 148.0 | 1.637 | 147.0 | 1.633 | 146.1 | 1.630 |
| 18393+0700 | J 101 | 243.2 | 5.408 | 243.3 | 5.454 | 243.4 | 5.500 | 243.5 | 5.546 | 243.6 | 5.593 |
| 18489+1615 | STF 2400 A, BC | 160.9 | 10.598 | 160.8 | 10.740 | 160.7 | 10.882 | 160.6 | 11.024 | 160.5 | 11.166 |
| 20333+3323 | HJ 1535 AC | 193.1 | 31.162 | 193.6 | 31.491 | 194.0 | 31.823 | 194.4 | 32.155 | 194.8 | 32.490 |
| 23460-1841 | H 2 24 | 135.4 | 6.907 | 135.3 | 6.922 | 135.3 | 6.937 | 135.3 | 6.953 | 135.2 | 6.968 |
| 23596-0748 | BU 731 | 296.8 | 1.667 | 297.3 | 1.673 | 297.8 | 1.679 | 298.3 | 1.684 | 298.8 | 1.690 |

The most common note indicators are either “C,” indicating a confirming observation, or a number (N) indicating the number of years since the system was last measured. This is only given for systems with $N \geq 50$ yr. Eleven systems are confirmed here. Since priority is given to both unconfirmed systems and to systems not observed recently, the time since last observation can be surprisingly large; for the systems in Table 2 the average time since the last observation is eight years (47 yr for those measures of reduced accuracy). Seventeen systems had not been observed in 50 yr or more and 4 had not been observed for at least a century. The maximum such time span was 108 yr for HJ 3085, last observed by Burnham (1906).

2.3. Orbit and Linear Calculations

Table 3 presents the mean relative positions for 225 systems with published orbital determinations or linear solutions. The

first six columns are identical to the corresponding columns of Table 2. Columns 7 and 8 give $O - C$ residuals (in θ and ρ) to the determination referenced in Column 9. The reference is either to a published orbit or linear calculation. Notes follow in Column 9. The objects in Table 3 tend to be more frequently observed than those in Table 2. Here mean and median separations of 22. $''$ 12 and 20. $''$ 38 are determined, with a mean time interval since last observation of only 4.6 yr. For the subset of orbit pairs ($N = 70$), the mean and median separations are 4. $''$ 35 and 1. $''$ 73 and the mean time interval since the last observation of 2.7 yr. In 11 cases, of possible solutions it is not yet possible to ascertain which is the preferred determination and additional residual lines are provided.

2.3.1. New Orbital Elements

New orbits are presented in Table 4. In this table, the pairs are identified by their WDS and discoverer designations. The orbital

Table 7
Double Stars not Found

| Coordinate α, δ (2000) | Discoverer Designation | Most Recent Published Observation | | | Published Magnitude | | Notes |
|---------------------------------------|---------------------------|-----------------------------------|---|-------------------------------|---------------------|-----------|-------|
| | | Date | Position Angle θ ($^\circ$) | Separation ρ ($''$) | Primary | Secondary | |
| 00589+3230 | SEI 10 | 1894 | 100 | 12.4 | 9.5 | 10.0 | 1 |
| 00595+3202 | SEI 11 | 1894 | 359 | 8.5 | 10.0 | 10.5 | 1 |
| 02413+2659 | L 55 | 1910 | 50 | 6.8 | 8.0 | 9.0 | 2 |
| 05347–0424 | SE 4 AC | 1859 | 86 | 51.5 | 7.7 | | 3 |
| 05347–0424 | SE 4 AD | 1859 | 297 | 10.9 | 7.7 | 8.2 | 2 |
| 06336+0910 | TDS 3923 | 1991 | 230 | 3.4 | 11.2 | 11.4 | 2 |
| 09342+0241 | WAM 2 | 1932 | 193 | 3.4 | 11.1 | 11.5 | 2 |
| 10425–0231 | BAL 525 | 1894 | 345 | 3.3 | 9.4 | 11.9 | 2 |
| 11205+1841 | TDS 7797 | 1991 | 251 | 6.0 | 9.7 | 11.6 | 2 |
| 18129–1820 | OL 163 | 1934 | 290 | 3.0 | 8.9 | 10.0 | 2 |
| 18188–1804 | OL 104 | 1921 | 213 | 3.0 | 9.5 | 10.5 | 2 |
| 19296+7311 | PAL 1 AB | 1995 | 72 | 4.6 | 10.6 | | 3 |
| 19432+0448 | J 1290 | 1916 | 214 | 2.5 | 10.0 | 10.3 | 2 |
| 20051–1136 | H 4 3 | 1780 | 10 | 25.0 | 6.3 | | 3 |
| 21098+3143 | ES 2440 | 1930 | 202 | 5.0 | 10.9 | 11.9 | 2 |
| 23512+5123 | ALD 7 | 1916 | 202 | 4.2 | 10. | 10.9 | 4 |
| 23569+2457 | POU 5877 | 1897 | 22 | 17.2 | 10.6 | 11.8 | 2 |

Notes.

- 1: Neither component seen on POSS plate; may be flaws on AC Potsdam plate.
 2: Companion not seen.
 3: Secondary magnitude unknown. Due to discovery method should be observable.
 4: Also not found by Heintz (1990) at Index Catalogue of Double Stars position.

elements follow giving the period (P in years), the semimajor axis (a in arcseconds), the inclination (i) and longitude of the node (Ω), both in degrees, the epoch of the most recent periastron passage (T_o in Besselian years), the eccentricity (e) and the longitude of periastron (ω in degrees). Following this is an evaluation of the orbit.

WDS18359+1659 (= STT 358) was beginning to exhibit systematic runoff from the orbit of Heintz (1995). Using the Orbit Catalog precepts (Hartkopf et al. 2001) the new orbit is evaluated as “preliminary,” but does give a reasonable mass sum estimate of $1.74 M_\odot (\pm 2.50 M_\odot)$ for an F8V and its companion. The *Hipparcos* parallax (30.41 ± 0.90 mas; van Leeuwen 2007) and new orbital elements imply a physical semimajor axis of 129 au.

WDS14165+2007 (= STF 1825) has its first orbit determination, evaluated as “indeterminate,” presented here. The pair has long been thought physical due to the similarity of their proper motions. The mass sum estimate is also reasonable here: $2.00 M_\odot \pm 0.28 M_\odot$ for an F6V and its companion. Similarly, the *Hipparcos* parallax (30.65 ± 0.64 mas; van Leeuwen 2007) and new orbital elements imply a physical semimajor axis of 105 au.

For both pairs, these elements may be most appropriately characterized as “improved but still provisional.” In both cases, the orbits should be sufficient to provide reasonable ephemerides for the next decade, but these elements will all require correction over the course of a complete orbit before they can be considered even approximately correct. These orbits along with their data are presented in Figure 1.

2.3.2. New Linear Elements

Selecting out all observed pairs with either a 30° change in their position angle or a 30% change in separation since the first observation catalogued in the WDS (Mason et al. 2001) revealed many pairs whose motion seemed linear. Their apparent linear

relative motions suggest that these pairs are either composed of physically unrelated stars or have very long orbital periods. Linear elements to these doubles are given in Table 5, where Columns 1 and 2 give the WDS and discoverer designations and Columns 3–9 list the seven linear elements: x_0 (zero point in x , in arcseconds), a_x (slope in x , in $'' \text{ yr}^{-1}$), y_0 (zero point in y , in arcseconds), a_y (slope in y , in $'' \text{ yr}^{-1}$), T_0 (time of closest apparent separation, in years), ρ_0 (closest apparent separation, in arcseconds), and θ_0 (position angle at T_0 , in degrees). See Hartkopf & Mason (2011b) for a description of all terms.

Table 6 gives orbital and linear ephemerides for the pairs in Tables 4 and 5 over the years 2012 through 2020, in two-year increments. Columns 1 and 2 are the same identifiers as in Tables 4 and 5, while Columns 3+4, 5+6, etc., through 11+12 give predicted values of θ and ρ , respectively, for the years 2012.0, 2014.0, etc., through 2020.0.

2.4. Double Stars Not Found

Table 7 presents 17 systems which were observed but not detected. Possible reasons for nondetection include orbital or differential proper motion making the binary too close or too wide to resolve at the epoch of observation, a larger than expected Δm , incorrect pointing of the telescope, and misprints and/or errors in the original reporting paper. It is hoped that reporting these will encourage other double star astronomers to either provide corrections to the USNO observations or to verify the lack of detection. Notes to some of these pairs, highlighting some possible reasons for non-detection, are appended to the table. In all cases, the position angle, separation and magnitudes are from the discoverer of the pair.

Thanks to James Hilton for his assistance with MP 50 Virginia. The continued instrument maintenance by the USNO instrument shop, Gary Wieder, Chris Kilian, and Eric Ferguson, makes the operation of a telescope of this vintage a true delight.

Thanks also to Ted Rafferty (USNO, retired) for his assistance with equipment upgrades and maintenance, and the foresight to initiate the secondary camera project.

REFERENCES

- Baize, P. 1978, IAU C26 Circ., 76
- Benavides, R., Rica, F., Reina, E., et al. 2010, JDSO, **6**, 30
- Brendley, M., & Hartkopf, W. I. 2007, IAU C26 Circ., 163
- Brendley, M., & Mason, B. D. 2007, IAU C26 Circ., 163
- Burnham, S. W. 1906, A General Catalogue of Double Stars within 121° of the North Pole (Carnegie Inst. Washington Publ. 5; Washington, DC: Carnegie Inst.)
- Cvetkovic, Z., & Novakovic, B. 2006, SerAJ, **173**, 73
- DeRosa, R. J., Patience, J., Vigan, A., et al. 2012, MNRAS, **422**, 2765
- Docobo, J. A., & Costa, J. M. 1984, IAU C26 Circ., 92
- Docobo, J. A., & Ling, J. F. 2009, AJ, **138**, 1159
- Docobo, J. A., Tamazian, V. S., Andrade, M., & Melikian, N. D. 2003, AJ, **126**, 1522
- Douglass, G. G., Hindsley, R. B., & Worley, C. E. 1997, ApJS, **111**, 289
- Drummond, J. D., Christou, J. C., & Fugate, R. Q. 1995, ApJ, **450**, 380
- Fekel, F. C., Scarfe, C. D., Barlow, D. J., et al. 1997, AJ, **113**, 1095
- Friedman, E. A., Mason, B. D., & Hartkopf, W. I. 2011, IAU C26 Circ., 175
- Friedman, E. A., Mason, B. D., & Hartkopf, W. I. 2012, IAU C26 Circ., 176
- Gorshanov, D. L., Shakht, N. A., & Kisseliev, A. A. 2006, SvA, **49**, 386
- Grosheva, E. A. 2006, SvA, **49**, 397
- Hale, A. 1994, AJ, **107**, 306
- Hartkopf, W. I., & Mason, B. D. 2001, IAU C26 Circ., 143
- Hartkopf, W. I., & Mason, B. D. 2009, AJ, **138**, 813
- Hartkopf, W. I., & Mason, B. D. 2010, IAU C26 Circ., 170
- Hartkopf, W. I., & Mason, B. D. 2011a, AJ, **142**, 56
- Hartkopf, W. I., & Mason, B. D. 2011b, Catalog of Rectilinear Elements, Published in Second USNO Double Star CD 2006.5, <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1>
- Hartkopf, W. I., Mason, B. D., & Worley, C. E. 2001, AJ, **122**, 3472, <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6.html>
- Hartkopf, W. I., Tokovinin, A., & Mason, B. D. 2012, AJ, **143**, 42
- Hauser, H. M., & Marcy, G. W. 1999, PASP, **111**, 321
- Heintz, W. D. 1990, ApJS, **74**, 275
- Heintz, W. D. 1995, ApJS, **99**, 693
- Heintz, W. D. 1997, ApJS, **111**, 335
- Hopmann, J. 1960, MiWie, **10**, 227
- Hopmann, J. 1970, Astron. Mitt. Wien, **5**, 217
- Hopmann, J. 1974, Astron. Mitt. Wien, **17**, 387
- Kiselev, A. A., Romanenko, J. G., & Kalinichenko, O. A. 2009, SvAL, **86**, 148
- Kiyaeva, O. V., Kisseliev, A. A., Polyakov, E. V., & Rafal'skii, V. B. 2001, SvAL, **27**, 391
- Mason, B. D., Douglass, G. G., & Hartkopf, W. I. 1999, AJ, **117**, 1023
- Mason, B. D., Hartkopf, W. I., & Friedman, E. A. 2012, AJ, **143**, 124
- Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2007, AJ, **134**, 1671
- Mason, B. D., Hartkopf, W. I., Wycoff, G. L., & Holdenried, E. R. 2006, AJ, **132**, 2219
- Mason, B. D., Hartkopf, W. I., Wycoff, G. L., et al. 2004a, AJ, **127**, 539
- Mason, B. D., Hartkopf, W. I., Wycoff, G. L., et al. 2004b, AJ, **120**, 3012
- Mason, B. D., McAlister, H. A., Hartkopf, W. I., & Shara, M. M. 1995, AJ, **109**, 332
- Mason, B. D., Wycoff, G. L., Hartkopf, W. I., Douglass, G. G., & Worley, C. E. 2001, AJ, **122**, 3466, <http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/wds.html>
- McAlister, H. A., Hartkopf, W. I., Hutter, D. J., & Franz, O. G. 1987, AJ, **93**, 688
- Muterspaugh, M. W., Hartkopf, W. I., Lane, B. F., et al. 2010, AJ, **140**, 1623
- Novakovic, B., & Todorovic, N. 2006, SerAJ, **172**, 21
- Olevic, D., & Cvetkovic, Z. 2003, IAU C26 Circ., 150
- Olevic, D., & Jovanovic, P. 2001, SerAJ, **163**, 5
- Popovic, G. M., & Pavlovic, R. 1996, BABel, **153**, 57
- Rica, F. M. 2012, JDSO, **8**, 127
- Roberts, L. C., Jr., McAlister, H. A., Hartkopf, W. I., & Franz, O. G. 1995, AJ, **110**, 2463
- Scardia, M. 1983, AN, **304**, 257
- Scardia, M. 2003, IAU C26 Circ., 149
- Scardia, M., Prieur, J.-L., Koechlin, L., & Aristidi, E. 2002, IAU C26 Circ., 146
- Scardia, M., Prieur, J.-L., Pansecchi, L., & Argyle, R. W. 2008, IAU C26 Circ., 165
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R. W., & Sala, M. 2010, AN, **331**, 286
- Scardia, M., Prieur, J.-L., Pansecchi, L., et al. 2007, AN, **328**, 146
- Seymour, D., & Hartkopf, W. 1999, IAU C26 Circ., 139
- Seymour, D., Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2002, AJ, **123**, 1023
- Söderhjelm, S. 1999, A&A, **341**, 121
- van Leeuwen, F. 2007, A&A, **474**, 653
- Zeller, G. 1965, AnWie, **26**, 111
- Zirm, H. 2007, IAU C26 Circ., 161
- Zirm, H. 2008, IAU C26 Circ., 166
- Zirm, H. 2011, JDSO, **7**, 24
- Zirm, H. 2013, IAU C26 Circ., 179